Intel® 810 Embedded Client Reference Design — Thermal Design Summary

Scalable Platform with Integrated Flat Panel Display

Application Note

June 2001

Order No: 273548-001

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Revision History

Date	Revision	Description
June 2001	001	Original release of the document

1.0 Introduction

This document outlines the methodology used to design a thermal management solution for the Intel® Embedded Client Reference Design. The thermal modeling techniques used to design and optimize the solution are presented, with emphasis on the reasoning used to develop the final system level thermal solution. The information is directed toward Intel customers who want to use the reference design as a baseline for accelerating the development of their own dedicated client.

This document includes the names and contacts of manufacturers, drawings, engineering analysis, and test data. In addition, recommendations are given to improve the thermal design.

This document also discusses the design and modeling approach used to develop the natural convection thermal solution for the dedicated client in a minimized package size. The dedicated client reference design has many requirements that limit the design envelope for the thermal solution. In order to overcome these limitations, the design team utilized the latest computer-aided simulation tools.

Note: The information provided in this document is for reference only and additional validation must be considered prior to implementing the design into high-volume manufacturing.

Several limitations, such as packaging, performance, time, and resources limited the development of the thermal solution. The dedicated client's chassis was designed to minimize the overall footprint of the package. Factors controlling the packaging included:

- The flat panel display, which is 10" wide by 7.5" long
- The dedicated client's performance required an Intel® Celeron™ processor with scalability up to 566 MHz with a natural convection solution
- An IDE hard drive
- Up to 256 Mbytes of SDRAM memory
- A 59 Watt power supply
- Other heat dissipating devices

The final challenge of the design was time. In order to satisfy project constraints, the solution had to be designed, modeled, prototyped, and verified within six months.

Note: Prototype parts have been fabricated for verification tests and marketing purposes. Thermal verification testing is not adequate for statistical purposes. The intent was only to verify that the thermal components were performing within reasonable expectations, based on computer modeling and manufacturer specifications. The information contained in this document is for informational purposes only.

2.0 Design Background Information

2.1 Intel Architecture

The primary objective of this effort was to design a natural convection thermal management solution that would allow the use of the Celeron processor up to 566 MHz along with the other electronic devices. The architecture of the reference design allows for the use of all Intel Celeron

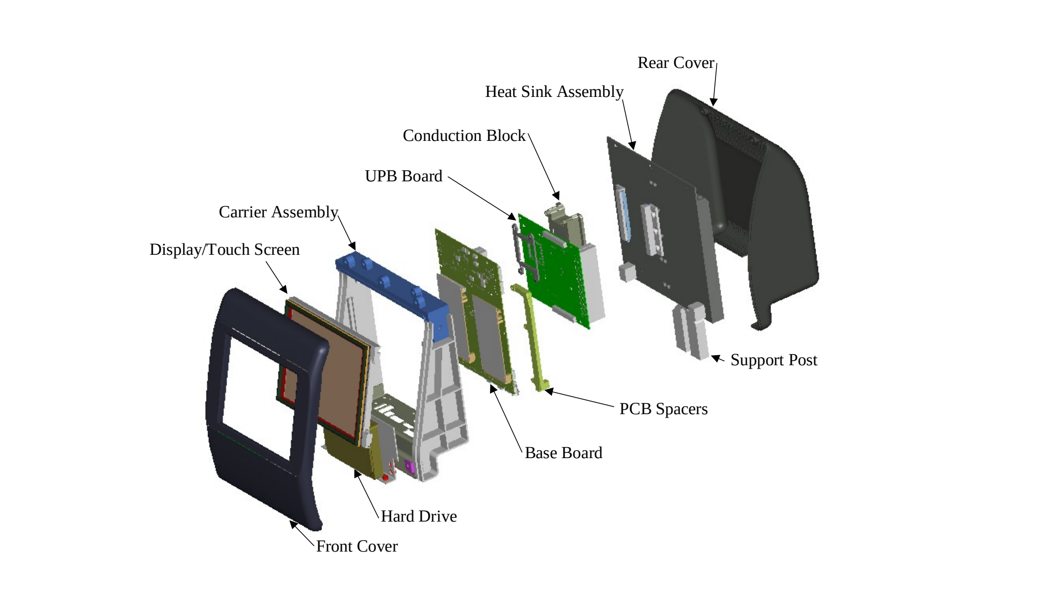
and Pentium III processors. However, the thermal solution for this reference design is optimized for the Celeron 566 MHz processor operating at ambient temperatures up to 50° C. It may be possible to use the natural convection solution for processors including the Pentium III, but this design has only been modeled and tested with the Celeron 566 MHz processor. It is the responsibility of interested parties to model and test the natural convection thermal solution with other parameters not detailed in this document.

2.2 Size Constraints

The size constraint of this dedicated client reference design is a primary factor that limited the design of the natural convection thermal solution. The chassis, as shown in Figure 1, is about 11 " wide by 15" high and 5.5" thick. The chassis houses all the components, including the flat panel display, hard drive, two PCBs, PMC boards, power supply components, and the natural convection thermal solution. The chassis consists of a carrier assembly that is the skeletal structure that holds the hard drive, PCBs, and thermal solution. The interior components are sealed by a front and rear housing assembly. Figure 2 illustrates the chassis assembly and how the carrier and other components are assembled.

Figure 1. Embedded Client Reference Design Physical Appearance

Figure 2. Exploded Assembly View of the Embedded Client Reference Design



2.3 Temperature Considerations

The dedicated client must be operational at an ambient temperature of 50° C. At this extreme operating temperature, the allowable temperature rise for the Celeron 566 MHz processor is 40° C. The Celeron 566 MHz processor has been specified to have a maximum allowable junction temperature (T_{jmax}) of 90° C and a thermal design power (TDP) of 14.9 W, based on the Intel Celeron Processor up to 850 MHz datasheet (order number 24365817).

These conditions result in a thermal solution that provides a junction-to-ambient thermal resistance of about 2.7° C/W. This level of thermal resistance has been found to be acceptable for PC applications with common thermal management techniques. However, typical PC applications have active thermal solutions with a heat sink and forced airflow. In this reference design, the intent was to develop a natural convection solution that relies only on natural bouyancy for airflow. To add margin to the design, the actual natural convection solution detailed in this document is optimized to accommodate a processor with a TDP of 20 W and a T_{jmax} of 90° C.

2.4 Other Design Factors

All of the following parameters and constraints also contribute to minimizing the design space for the thermal management solution.

1. Consideration was taken to make the thermal solution manufacturable at reasonable costs.
2. It was assumed that separate design iterations would be done to make the thermal solution more producible and cost-effective prior to high-volume manufacturing.

3. Reliability of the dedicated client was important. The product life of typical dedicated clients is up to seven years, so the components of the thermal solution had to accommodate this time frame.
4. The design had to be easily maintained for general maintenance and system upgrades.

3.0 Proposed Thermal Solution

Note: The designs presented in this document are Intel intellectual property and appropriate United States and foreign patents are pending.

The proposed natural convection thermal management solution for the dedicated client in the embedded form factor consists of a conduction block and an aluminum extruded finned heat sink. The proposed solution, which is illustrated in Figure 3 and Figure 4, addresses all the device's constraints and parameters.

The processor resides on the Universal Processing Block (UPB) PCB and does not directly contact the heat sink. To conduct the heat from the processor, an aluminum block is added that provides a thermal path from the processor to the heat sink. The conduction block is secured to the processor assembly via mounting holes and a stiffener plate on the underside of the UPB PCB. A high conductivity thermal interface material needs to be used for the processor and conduction block interface. The conduction block is secured to the heat sink by using a wedge lock mechanism to firmly pull the block to the heat sink.

The heat sink is an extruded aluminum part with a 0.1875" base and multiple fins. The heat sink has been optimized for maximum conduction and natural convection. As shown in Figure 4, the heat sink is 10.5" wide by 11" long and 1" thick. In addition, a folded fin-type aluminum heat sink was designed to accommodate low and medium volume production. This design dispenses with tooling costs associated with extrusions, but adds labor costs of cutting and binding stock aluminum.

The hard drive is mounted to an aluminum plate that is intended to spread the heat over a larger area, thus minimizing the device temperature. It may be possible to improve the thermal path to the hard drive plate by using a thermal interface material (TIM) between the hard drive and plate interface.

The hard drive plate is also attached firmly to the I/O plate. The I/O plate is an aluminum part that is exposed to the outside ambient air. The intent is to spread heat to the I/O plate and dissipate via natural convection.

The graphics memory controller hub (GMCH) is a component of the processor chip set that dissipates about 4 W of thermal power, and needs a heat sink. For the purposes of this document, a commercial over-the-counter (COTS) heat sink was used to dissipate heat from the device. An aluminum pin fin-type heat sink from Wakefield Engineering was used, part number 655-53. This heat sink was secured to the device using double-sided pressure sensitive thermal tape.

The thermal management components and the client's other devices were modeled to provide adequate cooling for the processor in the low-profile embedded form factor. Computer-aided design and analysis software was used to generate detailed thermal and computational fluid dynamic simulation models of the computing appliance.

Figure 3. Embedded Client Reference Design Proposed Thermal Solution

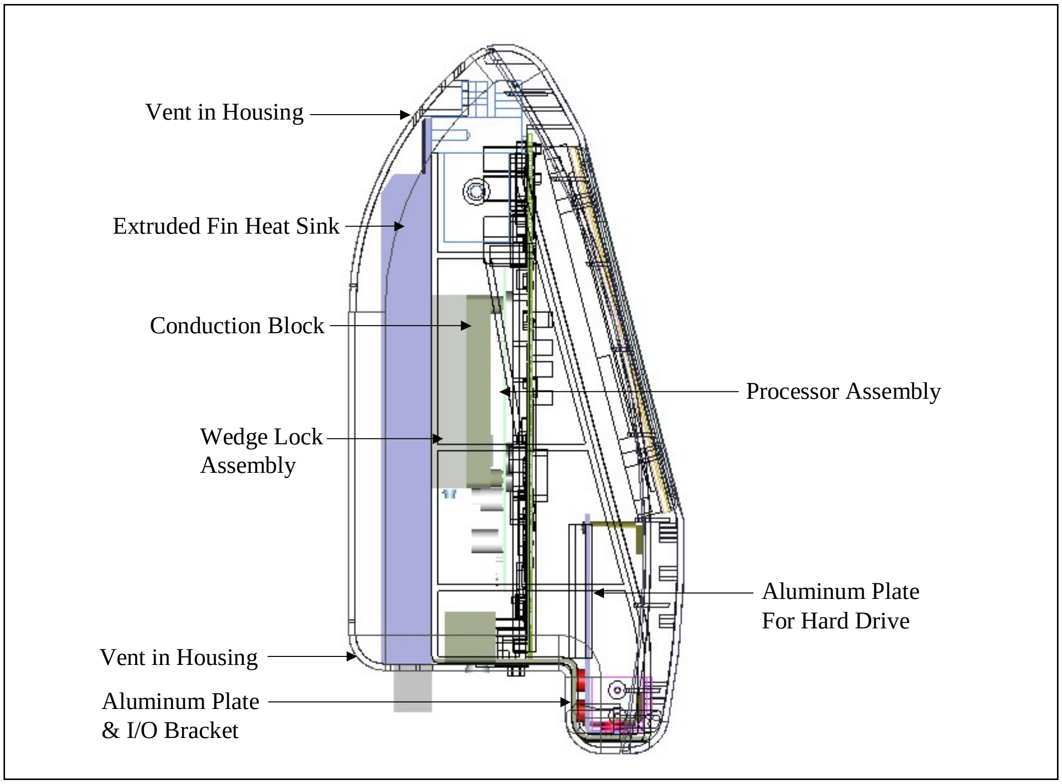
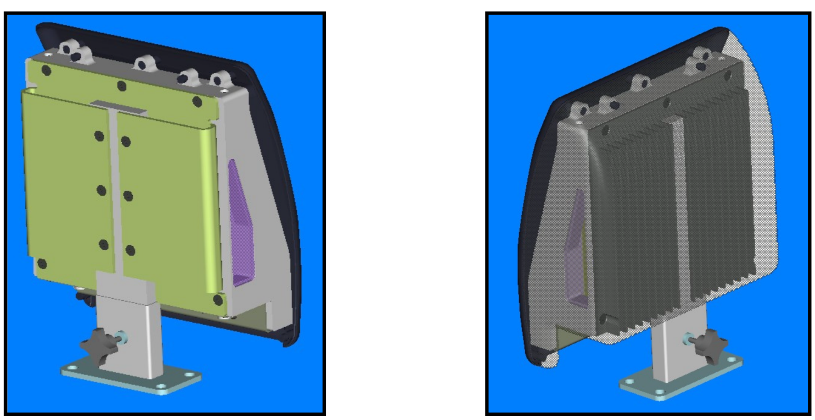


Figure 4. Extruded Fin and Folded Fin Heat Sink



Folded from Aluminum Sheet
- Cost effective in low volumes
- No tooling costs

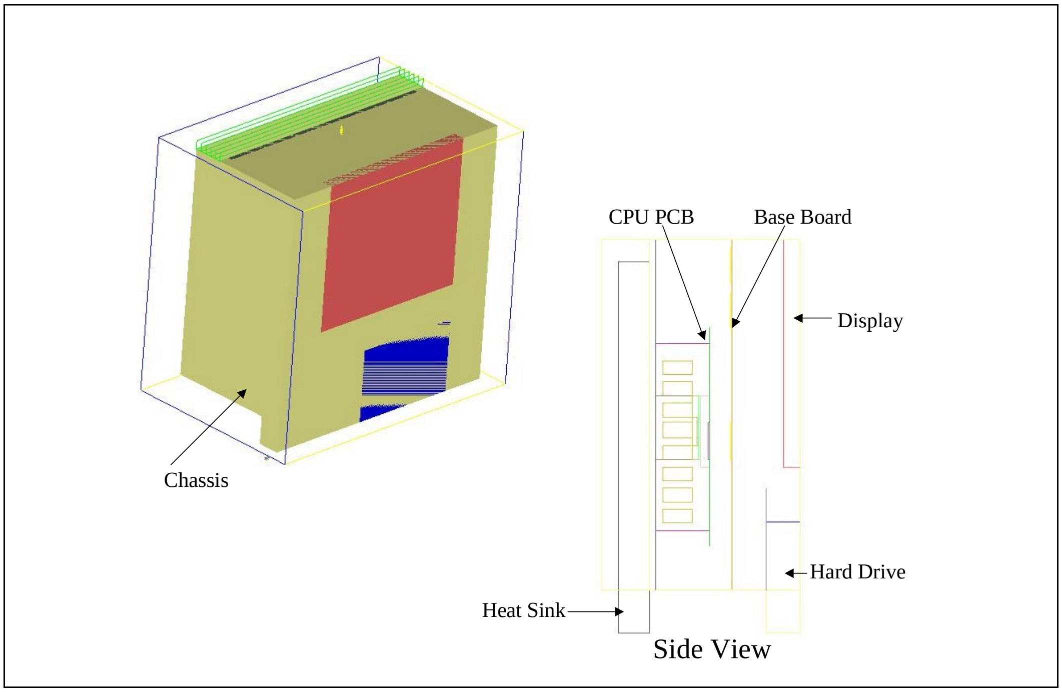
Extruded Aluminum
- Cost effective in high volumes
- Tooling costs

4.0 Modeling the Proposed Thermal Solution

The detailed model of the dedicated client, shown in Figure 5, was used to monitor changes throughout the reference design. It contains all the major components involved in the modeling process. The simulation model was used to optimize the fin spacing of the heat sink, as well as the material used for the conduction block and heat sink. Other important factors include:

- The proposed thermal management solution was optimized using an electronics cooling software that simulates thermal and computational fluid dynamics (CFD), including natural convection.
- The individual components were modeled as solid bulk objects with thermal properties based on input provided by their respective manufacturers.
- Except for the processor, all of the components were modeled without individual heat sinks.
- To add margin to the thermal design, the processor;s thermal power was scaled up to 20W.
- The junction temperatures of all critical components were calculated and compared to the maximum operating temperatures prescribed by the various component manufacturers. The intent was to determine if any components were operating near their maximum operating conditions.
- Additional values were calculated, including the system pressure, airflow patterns, and airflow speeds.

Figure 5. Detailed Computer Model for Thermal and CFD Analysis



5.0 Modeling Results

The modeling effort was performed to optimize the design of the proposed solution prior to fabricating hardware. The results of this model were used to provide a thermal management solution that meets the thermal requirements of all electronic components, including the processor.

A number of design changes were analyzed and verified with the models prior to implementation. Initially, it was thought that the conduction block would have to be made of copper. But, after several modeling efforts, it was determined that aluminum would work. The model allowed the design team to optimize all the system features and ensure that the thermal requirements were met.

Table 1 summarizes the calculated temperature rise expected for critical components. The calculated values can be compared to the manufacturer's specified maximum values, which are also listed in the table. Results indicate that the thermal management solution provides the necessary thermal dissipation to meet the reference design's requirements. To add margin to the system thermal solution, heat sinks were added to the final design for components with temperatures nearing their maximum values.

Note: The computer models for ICEPAK* electronic cooling softwareare available upon request. Please contact an Intel field service engineer.

Table 1. Thermal and CFD Modeling Results

Component	TDP (W)	Calculate T (°C) Rise	Maximum Allowable T (°C) Rise
Celeron® Processor	20	39.6	40
GMCH Chip	4	46.2	50
Memory DIMM Chip	0.3125/chip	36.5	50

6.0 Available Collateral

Reference drawings for the thermal components referenced in this document are provided at www.developer.intel.com. With the exception of COTS materials, none of the parts have been validated for performance, or high volume manufacturing. Detailed mechanical files are available in Pro Engineer* 2000i* format. Please contact an Intel field service engineer for detailed files.

7.0 Related Documents

The following documents can be referenced for more information about the Intel Celeron processor and the Intel® 810 Chipset.

Table 2. Related Documents

Document	Order Number
Intel® Celeron™ Processor up to 850 MHz Datasheet	243658
AP-905, Intel® Pentium® III Processor Thermal Design Guidelines	245087
Intel® 810/810E Chipsets: GMCH Electrical and Thermal Specifications	298180
Intel® 810 Chipset Application: Thermal Design Considerations, AP-670	292228

8.0 Vendor List

Table 3 provides a vendor list as a service to our customers for reference only. The inclusion of this list should not be considered a recommendation, or product endorsement.

Table 3. Vendor List

Extruded Heat Sink in Low Quantities, Folded Fin Heat Sink in Low Quantities, and Chassis Covers, Carrier Assembly, I/O Plate, Hard Drive Plate, Conduction Block in Low Quantities
X Product Development David Aitchison 15820 N. 84th St. Scottsdale, AZ 85260 480-315-2775
Extruded Heat Sinks in High Quantities (500 qty. MIN)
Alcoa Engineered Products Kathy Naftzinger Cressona, PA 17929 866-778-9990
Interface Material
TBD